Conservation Tillage Systems for Cotton and Peanut Following Winter-Annual Grazing

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Abstract: Integrating livestock with cotton (*Gossypium hirsutum* L.) and peanut (*Arachis hypogaea* L.) rotations offers profitable alternatives for producers in the southeastern USA, but could result in excessive soil compaction, which can severely limit yields. A 2 year field study was conducted at two locations (both Plinthic Paleudults) in south Alabama to develop a conservation tillage system for integrating cotton and peanut production with winter annual grazing of stocker cattle under dryland conditions. Winter pasture and tillage were evaluated in a strip plot design with four replications. Winter pastures (main plots) were oat (*Avena sativa* L.) and ryegrass (*Lolium mutiflorum* L.). Tillage systems (subplots) included: 1) mouldboard plough + disking, 2) in-row subsoiling with a KMC subsoiler + disking, 3) no-till with KMC™ subsoiling, 4) paratill + disking, 5) no-till with paratilling 6) strict no-till, 7) disking, and 8) chisel plough + disking. We evaluated soil strength, seed cotton, and peanut yield. Soil compaction was increased by grazing to the 10-15-cm depth but conventional tillage or conservation tillage with non-inversion deep tillage alleviated this problem. Forage species did not affect cotton yields. However, peanut yields were 13% greater with oat than with ryegrass. Strict no-tillage resulted in the lowest yields (2.22 and 2.82 Mg ha^{-1} for cotton and peanut, respectively; 20% and 37% less than the mean for cotton and peanut yield, respectively) and non-inversion deep tillage (in-row subsoiling or paratilling) was necessary to maximise yields in both crops with no-tillage. Deep tillage did not increase cotton or peanut yields in conventional tillage. Oat was less risky than ryegrass due to better peanut yield. Integrating winter annual grazing with cotton and peanut can be achieved using non-inversion deep tillage in a conservation tillage system. This system offers producers the ability to increase income during winter months while protecting the soil from erosion, creating a more sustainable production system.

Key words: *Lolium mutiflorum* L., *Avena sativa* L., soil compaction, paratilling, in-row subsoiling, integrated systems.

INTRODUCTION

The southeastern USA contains 11% of the nation's farms. Two thirds of these farms have livestock operations, with beef the most common. Recent research in Alabama found that contract grazing of stocker cattle in winter-early spring supplied by independent cattle owners offers farmers net returns of from \$170-\$560 ha^{-1} for grazing periods of 100 to 140 days (Bransby *et al.*, 1999). Such a system is ideal for farmers with limited capital and also allows potential for added income for producer's doublecropping behind winter grazing of annual pastures.

Soil management strategies that improve soil quality include conservation tillage, cropping intensification, and inclusion of sod-based rotations. Crop rotation is critical to cropping intensification and has long been recognised as being agronomically and economically beneficial (Reeves, 1994). Short-term forage rotations with row crops not only offer reduced economic risks for producers but also could increase soil organic carbon, which improves soil quality and productivity, while enhancing profitability for producers. However, winter-annual grazing may result in excessive soil compaction, which can severely limit yields of double-cropped cash crops (Miller *et al.*, 1997). Additionally, little is known about the direct impact of short-term grazing on soil properties.

Research in Alabama indicates that peanut producers experienced problems with poor seedbed conditions in no-till systems due to compaction (Hartzog and Adams, 1989). In-row subsoiling has not resulted in sufficient yield increases to justify this practice in conventional tillage, but in no-till systems (strip-tillage) this practice has been beneficial (Oyer and Touchton, 1988). Increased soil compaction also limits yield of cotton on sandy coastal plain soils, and in-row subsoiling to a depth of 30-50 cm at planting is required to maintain cotton yields on these soils (Raper *et al*., 1994; Reeves and Mullins, 1995). Tillage requirements for cotton and peanut following winter-annual grazing have not been researched or developed.

The objective of this study was to compare two winter pasture forages under grazing to determine their residual effect on cotton and peanut production, and identify an optimal tillage system for cotton and peanut grown following winter-annual grazing.

MATERIALS AND METHODS

Experiments were conducted at the Alabama Agricultural Experiment Station's Wiregrass Research and Extension Center (WGS) (31° 24'N, 85° 15'W), and Gulf Coast Research Station (GCS) (31° 24'N, 85° 15'W) in the coastal plain of southeastern Alabama, USA. Soils at the sites are a Dothan sandy loam for the WGS location and Malbis sandy loam for the GCS location (both Plinthic Paleudults[1]). The climate for these areas is humid subtropical, with a mean annual air temperature and precipitation of 18° C and 1400 mm for WGS and 19° C and 1625 mm for GCS, respectively.

Table 1. Species, cultivars, plant density, planting date, row spacing, tillage system, and environmental observations in 2001 and 2002, Wiregrass and Gulf Coast Experiment Stations, AL, USA.

Location	Species	Cultivar	Plant density	Planting date	Row spacing	Tillage	Observations
Wiregrass			------ha^{-1}------				
	Oat	Harrison	160 kg	20 Oct. 2000	17-cm	Conventional	
	Ryegrass	Marshall	35 kg	20 Oct. 2000	Broadcast	Conventional	
	Cotton	Suregrow 125B/R	110,000 seed	25 May 2001	91-cm	Variable†	Wet summer
	Peanut	Georgia Green	115 kg	25 May 2001	91-cm	Variable	
	Oat	Mitchell	160 kg	10 Nov. 2001	17-cm	No-till	
	Ryegrass	Marshall	35 kg	10 Nov. 2001	Broadcast	No-till	
	Cotton	Suregrow 125B/R	115,000 seed	24 May 2002	91-cm	Variable	Dry summer
	Peanut	Georgia Green	115 kg	24 May 2002	91-cm	Variable	
Gulf Coast							
	Oat	Citation	135 kg	1 Dec. 2000	17-cm	Conventional	
	Ryegrass	Gulf	35 kg	1 Dec. 2000	17-cm	Conventional	
	Cotton	Paymaster 1218 BR	140,000 seed	5 June 2001	96-cm	Variable	Wet summer
	Peanut	Georgia Green	120 kg	5 June 2001	96-cm	Variable	
	Oat	Mitchell	160 kg	10 Nov. 2001	17-cm	No-till	
	Ryegrass	Marshall	35 kg	10 Nov. 2001	Broadcast	No-till	
	Cotton	Suregrow 215 BR	140,000 seed	2 June 2002	96-cm	Variable	Wet fall
	Peanut	Georgia Green	120 kg	2 June 2002	96-cm	Variable	

†Treatment variable: two forage species and eight tillage systems.

Winter forages and summer tillage were evaluated in a strip-plot design with four replications. Winter forages (main plots) were oat and ryegrass. Grazing was continuous through contract grazing from January - April in both years and locations (average grazing time = 72 days). The stocking rate was 4.9 head ha^{-1} at both locations. During the spring-summer, the experimental area was divided into peanut and cotton areas, which were rotated each year. The summer crop tillage practices were: 1) mouldboard ploughing (30-cm depth) + disk/level (10-15 cm depth) after winter grazing, 2) in-row subsoiling with a narrow-shanked (3-cm wide) forward-angling subsoiler (KMC, Kelley Manufacturing Co. Tifton, GA[1]) (35-40 cm depth) + disk/level, 3) no-till with KMC in-row subsoiling, 4) under-the-row paratilling (45-50 cm depth) + disk/level; 5) no-till with paratilling, 6) strict no-till, 7) disk/level only, and 8) chisel ploughing (20-cm depth) + disk/level. Cultural practices for winter

[1] [1] Use of company name does not imply USDA approval or recommendation of the product or company to the exclusion of others which may be suitable

annual grazing and summer crops were recommended by the Auburn University Extension Service. Lime, P, and K were applied according to Auburn University soil test recommendations.

Cone index measurements were determined using a recording penetrometer at the Wiregrass location immediately before grazing, immediately after grazing, and during the bloom period of cotton and peanut in 2002, averaged over three row positions related to traffic patterns (Siri-Prieto *et al*., 2003). Cotton and peanut yields were determined from 15.2 m of two rows selected from the middle four rows of each plot.

All data were subjected to analysis of variance (ANOVA) using the Statistical Analysis System (Little *et al*., 2002). Due to widely varying environmental conditions, the data were analysed by year. Where location by tillage system interactions occurred for response variables, data were analysed and are presented by locations. Sources of variation were considered significant when the probability of greater F values were ≤ 0.10. Mean separations were made with LSD ($P \leq 0.10$) when sources of variation from the ANOVA were significant.

RESULTS AND DISCUSSION

Penetrometer measurements

Soil strength for tillage systems, averaged over three row positions, at three periods in 2002 are shown in Figure 1. Before grazing, in early winter 2002 (Figure 1-A), tillage impacted soil strength to the 30-cm depth. This indicates a residual effect of tillage from spring 2001 evident after 7 months. Paratilling presented the lowest soil strength to a depth of 30-cm, and chisel ploughing exhibited lower soil strength than no-till only in the upper 10-cm. A similar residual effect has also been reported by Touchton and Johnson (1982) in which subsoiling a summer row crop provided significant yield benefits to a subsequent small grain double crop without the need for a second subsoiling operation between crops.

After grazing, in spring of 2002 prior to tillage operations for cotton and peanut, (Figure 1-B), differences among tillage systems were smaller than before grazing (Figure 1-A). Cattle compacted the soil to a depth of approximately 10-15-cm. These results agree with those of Mullins and Burmester (1997), who found that cattle compacted the soil surface to a depth of 15-cm on a silt-loam soil in north Alabama. During mid-summer of 2002, when cotton and peanut were flowering and most sensitive to deficits in soil water, paratilling or chiseling eliminated compaction caused by grazing in the soil surface, while strict no-tillage presented the highest values (close to 2.0 MPa in the soil surface), potentially limiting root growth (Figure1-C). Busscher *et al*. (1988) found that similar soils that were disked had average lower soil strength than conservation-tilled soils throughout the upper 60-cm of the profile. .

Cotton yield

Seed cotton yield was different between locations due to different weather conditions and variations in management practices (Table 1 and 2). Seed cotton yields averaged 3.85 Mg ha^{-1} in 2001 and 3.14 Mg ha^{-1} in 2002 for the Wiregrass location and 2.21 Mg ha^{-1} in 2001 and 1.36 Mg ha^{-1} in 2002 for the Gulf Coast location. Even though there was a difference between years and locations, no forage species or locations X forage species interactions occurred for seed cotton yield. Plant populations affected by forage species (data not shown) had no impact on yield for these two years and locations. Seed cotton yields were affected by forage species by tillage system interactions in 2002 (data not shown), however, strict no-tillage (2.45 and 1.92 Mg ha^{-1} seed cotton averaged over locations for 2001 and 2002, respectively) resulted in the lowest yields (22% less than the mean in 2001 and 17% less than the mean in 2002). There were no location by tillage system interactions and deep tillage was necessary to maximise yields at both locations. Reeves and Mullins (1995) reported similar results, indicating that subsoiling was necessary for maximum cotton yields in coastal plain soils containing root-restricting soil layers. Comparing conventional tillage (disk, chisel, and mouldboard) vs. non-inversion deep tillage systems in no-till (under-the-row KMC or paratilling), the conservation systems with deep-tillage resulted in slightly higher yields (4% and 8% greater seed yield for 2001 and 2002, respectively, averaged over locations).

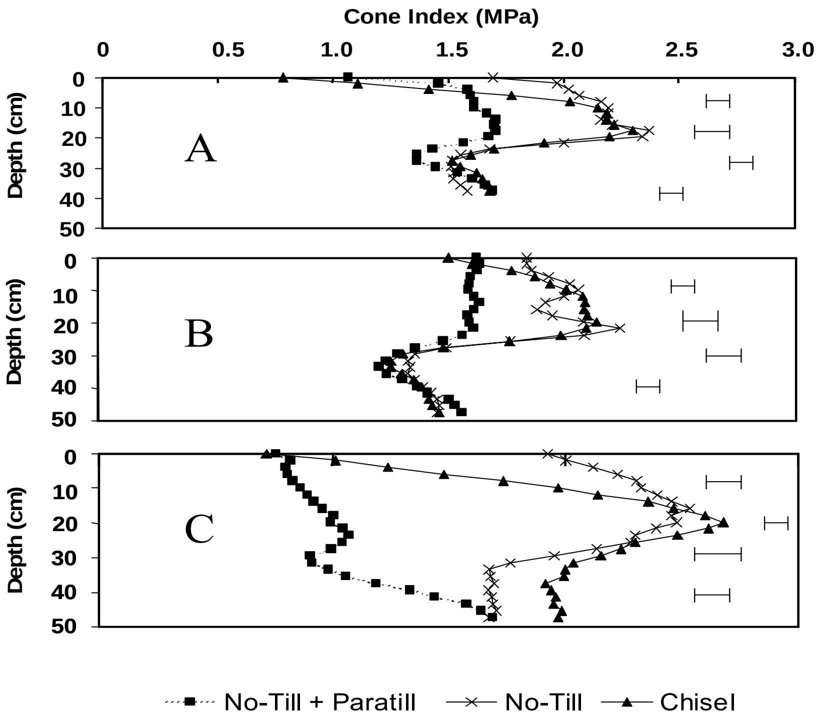

Figure. 1. Soil strength as affected by three tillage systems for three periods: A (before grazing); B (after grazing prior to tillage); and C (mid-summer, cotton and peanut flowering) at Wiregrass Station, AL, 2002. Data averaged over row position (in-row, untrafficked row, and trafficked row). Measurements made to a depth of 40-cm. in A, and to a depth of 50-cm for B, and C graphs. Horizontal bars are $LSD_{0.10}$.

Peanut yield

Peanut yield was also significantly different between locations due to different weather conditions and management practices (Table 1 and 2). Peanut yields averaged 4.25 Mg ha^{-1} in 2001 and 3.65 Mg ha^{-1} in 2002 for the Wiregrass location and 5.50 Mg ha^{-1} in 2001 and 2.58 Mg ha^{-1} in 2002 for the Gulf Coast location.

There was a significant impact of forage species on peanut yield at both locations with higher yields for peanut following oat than ryegrass. This did not appear to be related to plant density (data not shown). Additionally, we found no relationship between soil strength and forage species at the Wiregrass location two months after planting in 2002, but it was obvious that some factor was limiting peanut growth and yield following ryegrass. We speculate that ryegrass produced more root biomass than oat and that the dense root biomass from ryegrass may have negatively impacted peanut pegging.

Table 2. Effect of locations, winter forages species, and tillage systems by year on seed cotton and peanut yield at Wiregrass (WGS), and Gulf Coast (GCS) locations, AL, 2001-2002.

Effect	Seed Cotton Yield		Peanut Yield			
	Year		Year			
	2001	2002	2001	2002		
	---- Mg ha^{-1} ----					
Location						
WGS	3.85	3.14	4.25	3.65		
GCS	2.21	1.36	5.50	2.58		
LSD (0.10)	*0.40*	*0.25*	*0.40*	*0.40*		
Forage						
Oat	3.07	2.26	5.1	3.4		
Ryegrass	2.99	2.25	4.65	2.85		
LSD (0.10)	*ns†*	*ns*	*0.29*	*0.16*		
Tillage Systems				*WGS*	*GCS*	*2002 Location Mean*
Mouldboard + disk	2.96	2.16	5.31	3.29	2.25	*2.77*
Disk	2.89	--- ‡	4.89	3.75	2.44	*3.09*
Chisel + disk	3.15	2.24	5.41	3.76	2.80	*3.28*
KMC + disk	3.26	2.29	5.28	3.59	2.57	*3.08*
No-till + KMC	3.17	2.25	5.08	4.18	2.32	*3.25*
Paratill + disk	3.24	2.42	5.31	3.73	2.82	*3.28*
No-till + paratill	3.09	2.49	4.9	3.90	2.86	*3.38*
No-till	2.45	1.92	2.84	2.95	2.63	*2.79*
LSD tillage (0.10)	*0.41*	*0.42*	*0.58*	*0.42*	*0.56*	*0.45*

† ns = not significant
‡ data not available due to harvest failure

Peanut yields were affected by tillage system in both years. In 2001, strict no-tillage had the lowest yields (2.84 Mg ha^{-1} vs. 5.17 Mg ha^{-1} averaged over all tillage systems at both locations). In 2002, the lowest yields were with mouldboard ploughing and strict no-tillage; however, tillage systems by location interactions existed for 2002 due to strict no-tillage resulting in the lowest yield at the Wiregrass location while mouldboard ploughing resulted in the lowest yields at the Gulf Coast location. Averaged across locations within no-tillage plots, peanut yields were similar for in-row subsoiling with the KMC implement and paratilling. However, at the Wiregrass location, in-row subsoiling resulted in an 8 % greater yield than paratilling while at the Gulf Coast location, paratilling resulted in an 11% greater yield than in-row subsoiling.

The need for deep tillage within no-tillage systems was more critical following ryegrass than oat forage for peanut yield (data not shown). Deep tillage conducted within conventional tillage did not increase peanut yield. These results agree with those of Oyer and Touchton (1988), who found advantages to previous deep tillage in a no-till system (24% increase in peanut yield averaged over two years), but no advantages of in-row subsoiling in conventional tillage systems.

CONCLUSIONS

Strict no-tillage resulted in the lowest seed cotton yields (22% and 17% less than the mean for 2001 and 2002, respectively) and non-inversion deep tillage was necessary to maximise cotton yields in conservation tillage systems following winter grazing. Within no-tillage systems, there were no differences in seed cotton yields between in-row subsoiling with the KMC implement and paratilling. Deep tillage in conventional tillage systems did not increase yield.

Peanut following grazing of oat had higher yield than peanut following grazing of ryegrass. Some factor other than plant density is likely responsible for the reduced peanut yield following ryegrass compared to oat. Peanut yields were affected by tillage system in both years and both locations. In 2001, strict no-tillage had the lowest yields (45% less than the mean) and in 2002, strict no-tillage and mouldboard had the lowest yields (12% less than the mean). Non-inversion deep tillage was necessary to maximise yields within no-tillage systems in both locations and both years. For peanut, the need for non-inversion deep tillage in conservation systems was more important following ryegrass than oat forage. Deep tillage in conventional tillage did not increase peanut yield.

In conclusion, integrating winter-annual grazing with cotton or peanut on sandy soils with hardpans can be achieved using non-inversion deep tillage in conservation tillage systems. For peanut, oat appears less risky than ryegrass, but cotton yields were similar between forages. Integrating winter-annual grazing offers producers the ability to increase income during winter months while protecting soil from erosion and reducing the risk of loss of soil C.

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